THE ADEQUACY OF INFLATION-TARGETING MONETARY POLICY AND EURO ZONE PARTICIPATION FOR THE CENTRAL-EAST EUROPEAN COUNTRIES

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1. Introduction

Currently, the central banks of European nations with market economies have the primary statutory objective of achieving and maintaining price stability. The Czech, Hungarian and Polish national banks have already introduced inflation targeting, because these countries are European Union membership candidates, but they did not introduce the euro after their EU accession in 2004, despite it being a future obligation for them. These Central-East European countries have a unique style of capitalism, characterised by underdeveloped capital markets, poor savings accumulation and over-concentrated banking systems (Farkas 2011), resulting in substantial capital imports that accelerated the domestic credit booms in the pre-crisis era (Kovács 2009, Árvai et al. 2009).

This paper aims to analyse the liquidity sensible environment that has defined the range of monetary policy decisions in the selected Central-East European member states over the last decade, using bond and currency markets as indicators and stock markets as control variables. First, it is necessary to define the monetary policy frameworks of these states and describe the expected potential impacts of these policies on, and assumptions regarding, capital markets. Second, it is necessary to analyse how these expectations measured against the experiences of the countries over the last decade. This study applies a method for examining the efficiency of capital markets and identifies different forms of collective

behaviours, such as contagion, divergence or interdependence; these phenomena influence the range of available monetary policy decisions.

Following these results, it is necessary to evaluate how inflation targeting supports future euro adoption by answering these questions:

1. Is there any convergence between the capital markets of the euro zone and the selected countries, as required by the Maastricht criteria[1]?
2. Are the national banks in the selected countries able to address financial market crises alone?

2. Theoretical background

This chapter summarises the frameworks, expectations and assumptions regarding capital markets and their interactions with inflation-targeting monetary policies, before defining the different forms of collective behaviours in capital markets.

2.1. Capital markets and inflation-targeting frameworks

Inflation-targeting monetary policy could be defined as a monetary framework that comprises the following four properties: (1) the goal of price stability, (2) an announced numerical or sequential inflation target within a given time period, (3) inflation-forecast targeting (Svenson 1997), and (4) high levels of transparency and accountability (Hamori and Hamori 2010). O'Sullivan and Tomljankovich (2012) summarise the primary benefits attributed to this approach in the literature as follows: substantial declines in inflation and output growth volatility in emerging economies reduces the probability of banking crises and noise in bond markets. The expected noise reduction became significant in light of an article by Bean et al. (2010), which summarises the presumptions of the pre-crisis monetary policy for both the US Federal Reserve System (FED) and the European Central Bank (ECB) – where the assumption of market efficiency as a working approximation for equity and credit markets and where price and financial stability are assumed to be mutually dependent.

The assumption of market efficiency and the expected reduction of noise in bond markets are connected to the first question of this study. The

[1] Focusing on the 4th and 5th criteria, which call for long-term interest rates of no more than two percentage points above the rate in the three EU countries with the lowest inflation over the previous year, and that a national currency's exchange rate remain within certain pre-set margins for two years.

Maastricht-type convergence of capital markets could be temporary or at least biased when they can be described by a complex capital market model, involving the phenomenon of collective behaviour on extreme days. To test these phenomena, this study focuses on the 3-month and 10-year maturities of bond and currency market developments and on the stock market as a control variable between January 1 2002 and August 31 2011 using daily closing values. Our objective is to explore the spill-over effects generated by the FED and ECB on the new EU member states that aspire to adopt the euro.

Bonanno et al. (2001) defined three statistical consequences of complexity in financial markets: first, time series have short and long range memories and only asymptotic stationarity; second, their sectoral intraday cross-correlations are high; and third, they demonstrate collective market behaviours during extreme market events. The contagion, divergence and interdependence terms are consistent with the latter two consequences, with interdependence ruling out any significant changes in the common movement between markets, contagion being important under a significant increase in cross market correlation and divergence being important under a decrease in cross market correlation.

Contagions can be broadly defined as the cross-country transmission of shocks or general cross-country spill-over effects, which do not need to be related to crises. This paper uses the World Bank's very restrictive definition[2] of contagions, as cross-country correlations that increase during "crisis periods" relative to correlations during "tranquil periods". Interdependence can be described as a situation where the difference between correlations under extreme and normal conditions is insignificant.

Definition: *Contagion* (1) occurs between $m_k m_j$ markets when the $\rho^{m_k m_j}$ cross-market correlation becomes significantly higher due to a shock derived from one market ($r^{m}_{n/x}$) spreading to others or as a result of other external factors (Forbes and Rigobon 2002; Campbell et al. 2002; Bekaert et al. 2005):

$$r^{m_i}_{n/x} \neq 0 \rightarrow \rho_n^{m_k m_j} < \rho_x^{m_k m_j}, \qquad (1)$$

[2] Forbes and Rigobon (2002) used the World Bank's (2012) definition as well.

Definition: *Interdependence* (2) occurs between $m_k m_j$ markets when the $\rho^{m_k m_j}$ cross-market correlation is not significantly different, but the level of correlation is consistently high (Forbes and Rigobon 2002):

$$r_{n/x}^{m_i} \neq 0 \rightarrow \rho_n^{m_k m_j} \approx \rho_x^{m_k m_j} \tag{2}$$

Definition: *Divergence* (3) occurs between $m_k m_j$ markets when the $\rho^{m_k m_j}$ cross-market correlation becomes significantly lower due to a shock derived from one market ($r_{n/x}^{m}$) spreading to others or as a result of other external factors (Bearce 2002):

$$r_{n/x}^{m_i} \neq 0 \rightarrow \rho_n^{m_k m_j} > \rho_x^{m_k m_j} \tag{3}$$

There could be a number of reasons behind the collective behaviour phenomenon, for example changes in market mood, herding, trade relations[3], credit channels or political connections. However, according to Jentsch et al. (2006), there is a more general reason for collective behaviour that derives from the dynamic properties of extreme events, as extreme events are nested functions of scale-free complex networks. The efficient market hypothesis is consistent with an Erdős and Rényi (1960) random graph or a competitive market model, but there is a more oligopolistic model of a scale-free network that has been developed by Barabási and Albert (1999). Networks among economic actors and financial markets or ordinary enterprises follow this model, according to Berlinger et al. (2011), Benedek et al. (2007), Lublóy (2005) and Vitali et al. (2011). Financial systems are primarily interconnected through the interbank lending market, as the results of Kovács (2009) and Bank for International Settlements (BIS 2011) suggest. Therefore, the vulnerability of a country will not depend on macroeconomic fundamentals or the general soundness of the individual banking systems alone, but will be affected by the maturity structure of foreign claims and the financial relationships between home and host institutions, as Árvai et al. (2009) suggests.

[3] The euro zone accounted for 52% of Hungarian exports and 55% of its imports in 2011 (KSH 2012); the euro zone accounted for 47% and 60% of Polish imports and exports in 2010 (GUS 2011, 112), while the corresponding figures for the Czech Republic were 53% and 67% (CZSO 2011).

2.2 The difference between the autonomy and independence of monetary policy

The possibility of barriers between capital markets raises a second question and obviously suggests a more intensive collaboration between the ECB and non-euro-area member states to support official liquidity and maintain the transmission mechanism. In optimal circumstances, a credible and independent central bank would be able to establish a path for short-term interest rates to anchor expectations about future policy rates to influence longer term interest rates (BoE 2000). For example, between September 2008 and February 2010, the reduction in the ECB's short term interest rates generally affected the three month Euro Interbank Offered Rate (EURIBOR) and, in parallel, most bank interest rates on loans for housing and consumption also declined (ECB 2010). Based on the deep economic relationships between the countries in this analysis and the euro zone, the monetary policy environments are already interconnected, with the potential consequence of narrowing the range of decisions available. The autonomy of monetary policy was defined by Plümper and Troeger (2008) and Obstfeld et al. (2005) as the ability of central banks to set prime rates according to macroeconomic conditions, or as the independence from the monetary policies in the key currency areas. This ability is reduced by the degree of monetary interdependence, which is based on trade relationships and cross-border production chains. Therefore, a floating exchange rate regime and free movement of capital does not necessary imply full monetary autonomy as the classic notion of the impossible trilemma would suggest. Global liquidity is able to limit this autonomy by increasing the vulnerabilities of a financial system through substantial mismatches across currencies, maturities and countries, while the supply of global liquidity stems from one or more "core countries" (BIS 2011). Therefore, the BIS recommends wider and more targeted interventions on the national (monetary liquidity) and international (IMF and other regional stabilisation funds) levels (referred to as "official liquidity") in domestic and foreign currencies when private funding or market liquidity contracts suddenly.

Uneven monetary autonomy and central bank independence are not contradictory because this "independence" only refers to its domestic institutional meaning under current law[4], where only the frameworks for

[4] ECB: article 130 of the Treaty on European Union; Act No. 6/1993 Coll. on the Czech National Bank, Article 1 and 6; Act CCVIII of 2011 on the Magyar Nemzeti Bank – Hungarian National Bank, Article 1; The Act on the National Bank of Poland of 29 August 1997, Article 56

central bank activities are defined by the law, instead of its operations. The turbulence in private liquidity and the cross-border lending and ownership in the banking sector suggest more intensive collaborations between EU-27 central banks and financial authorities[5] within and outside the euro zone. The next chapter briefly summarises the primary interactions among the ECB, the FED and the selected central banks with a focus on the patterns of pre-crisis and crisis collaborations.

3. Monetary policy decisions by the ECB and the FED

This paper defines two periods according to the ECB's and FED's interest rate decisions: "period A" covers the era of increasing and consistently high interest rates, while "period B" is a period of expansionary monetary policy with decreased interest rates on the short end of the yield curve and increasing yields on the long end. This chapter briefly summarises the main events of these periods, focusing mainly on the relationships between the ECB and the central banks (Czech National Bank – CNB, Hungarian National Bank – MNB, Polish National Bank – NPB) of the selected countries, especially in the year 2008.

3.1 Period "A"

A cautious monetary tightening characterised both ECB and FED monetary policy during the reconstruction phase after the dot-com bubble – the FED began to cautiously increase its primary credit interest rate from 2% to 6.25% between June 30, 2004 and August 17, 2007. This 42 month period was longer than the corresponding 18 month period when the ECB increased its main refinancing rate from 2% to 4% between December 6 2005 and June 13 2007. This tightening was triggered by the general increase of raw material, food and energy prices (MNB 2008), despite the emerging concerns regarding the sustainability of the housing sector. The FED kept interest rates high until August 17 2007, while the ECB waited until July 9 2008 and increased its interest rates to 4.25% until October 14 2008. This stable period was characterised by emerging risk management and securitisation issues.

[5] Despite the different institutional environments, for example there have been supreme financial supervision authorities in Hungary and Poland since 1999 and 2006, while in the Czech Republic it has been part of the central bank since 1993. (Act No. 6/1993 Coll., on the Czech National Bank; Hungary: law 124 in 1999; Poland: Act on Financial Market Supervision of 2006, No. 157, item 1119).

The ECB's measures to manage money market turbulence during the period from January to September 2008 can be grouped under three headings (ECB 2009):

1. The liquidity provision used earlier in the maintenance period to fulfil counterparties' reserve requirements.
2. Supplementary longer-term (3 and 6 month) refinancing operations occurring since July 2007.
3. Operations in conjunction with the US dollar Term Auction Facility: in 2007, the ECB established a reciprocal currency arrangement (swap line) with the Federal Reserve System – the Eurosystem provided funding in US dollars received via this 28-day and, later, 3-month swap line to its counterparts against collateral eligible for Eurosystem credit operations.

The intensification of the global financial crisis brought challenges for monetary policy in the selected countries, which experienced liquidity constraints in their interbank markets and tensions in their foreign exchange markets. Central bank responses varied depending on the economic conditions and monetary policy framework in place, for example ERM II participants adopted monetary policy measures that frequently mirrored moves by the ECB. However, central banks with inflation targets that did not participate in ERM II tightened their monetary policy stances at the beginning of 2008, with the aim of containing inflationary pressures stemming in large part from food and energy price increases and wage growth. In the first three quarters of 2008, the MNB and PNB each increased their main policy rates by a total of 100 basis points in several steps, while the CNB increased its main policy rate only once, by 25 basis points in February, a move that was reversed in August. The selected non-euro-area member states did not participate in ERM II in 2008, and their currencies appreciated and reached record levels against the euro in the first half of the year. In February 2008, Hungary replaced its exchange rate band for the euro with a free-floating exchange ratio reach its inflation target, thereby fulfilling the nominal Maastricht criteria (MNB 2008). However, after the deepening of the financial crisis in September, global deleveraging and severe problems in the functioning of interbank markets worldwide resulted in a rapid and pronounced depreciation of the Polish zloty and the Hungarian forint (ECB 2009).

As a result of the increasingly deepening crisis, a direct disinflationary effect emerged that affected demand and household consumption; this

trend was supported by the expansion of household foreign currency loans and redundancies in the labour market (MNB 2008).

3.2 Period "B"

Central banks had to operate under disrupted monetary policy transmission mechanisms: money market interest rates were largely affected by liquidity disturbances, caused by the lack of trust among market participants and significant declines in markets' balances, due to price decreases and problems with asset valuation (NBP 2009).

Period "B" is characterised by monetary easing; however, period "B" did not occur simultaneously at the ECB and FED (as shown by their policy rates): the FED reduced the prime rate between August 17 2007 and December 17 2008 until it reached 0.5%, while the ECB only reacted after the collapse of Lehman Brothers. The late reaction on the part of the ECB seems reasonable due to its previous liquidity enhancement measures and the significant increase in inflation, resulting from a price surge in the global agricultural and energy commodity markets in 2007 and the first half of 2008. Global inflationary pressures only eased in the second half of 2008; however, at the same time, the previously visible appreciation trend of the Central-East European (CEE) currencies was inverted due to growing risk aversion and the ensuing capital outflows from emerging markets (NBP 2009).

In the second half of 2008, the ECB's main refinancing rate declined from 4.25% to 1% until May 2009, and it tightened the interest rate channels from 200 basis points to 100 bps to reduce interbank market volatility. The financial system recovered quickly, but the crisis spread to the European bond market, causing heterogeneous risk premiums between euro-area member states.

The ECB took the following steps to enhance liquidity management from October to December 2008, as the Annual Report of the ECB (2009) describes:

1. Fixed rate tenders with full allotment (all bids were satisfied), signing to market participants that the ECB was willing to supply as much liquidity as needed to avoid a liquidity crisis.
2. A reduction of the corridor formed by the standing facility rates, i.e., the marginal lending facility and the deposit facility, from 200 to 100 basis points, aiming to further ease banks' liquidity management by offering less expensive central bank intermediation.

3. Supplementary longer-term refinancing operations: one for the length of the maintenance period, two with a maturity of three months, and one with a maturity of six months.
4. Additional US dollar and Swiss franc-providing operations. Market liquidity in the foreign exchange swap market was unusually low due to increased stress and market segmentation, causing US dollar financing to become extremely difficult for institutions outside the United States. The Eurosystem further reinforced its provision of US dollar liquidity to Eurosystem counterparts by adding collateralised repo operations, fulfilling all bids at a fixed rate with overnight, 7-day, 28-day and 3-month maturities, in parallel with EUR/USD foreign exchange swaps.

   On 15 October, the Swiss National Bank and the ECB jointly announced measures to improve liquidity in short-term Swiss franc money markets, whereby the Eurosystem would provide its counterparts with Swiss franc financing via a swap line at a fixed price and with a maximum allotment amount and a 7-day or 3-month maturity.

   The ECB did not undertake any foreign exchange operations in the currencies that participate in ERM II.
5. Expansion of the collateral list.

In response to the tensions that developed in financial markets in late October and November 2008, there was a joint international financial support programme for Hungary to ease the downward pressure on the forint and other currencies in the region. However, the deteriorating economic outlook and external vulnerabilities, combined with credit rating downgrades for Hungary in October and November, resulted in a further sharp depreciation of the zloty, the forint and the koruna (ECB 2009). On 21–22 October, the exchange rate of the forint was subject to significant devaluation pressure in excess of that justified by macroeconomic fundamentals, causing an increase in the base rate of 300 basis points to maintain the stability of the financial intermediary system, contain a further strengthening of capital outflows and devaluation expectations and make speculation against the forint more expensive (MNB 2008). In October and November 2008, the ECB signed agreements to provide euro liquidity to the Hungarian and Polish national banks to improve euro liquidity in their respective domestic financial markets via repurchase agreements worth up to 5 and 10 billion euro (ECB 2009).

Hungary was able to meet its external obligations (97% of GDP at the end of 2007) under these extreme market circumstances due to the

17-month Stand-By Arrangement provided by the IMF (€12.3 billion), ECB (€6.5 billion) and World Bank (€1 billion) under the Fund's fast-track Emergency Financing Mechanism procedures (IMF 2008). This programme had two key objectives: to reduce the government's debt-financing needs and maintain the liquidity and capital adequacy in the banking system. This joint credit line caused a 57% increase in the balance sheet of the Hungarian National Bank (MNB). The MNB took several steps to improve the distribution of interbank forint and FX liquidity and maintain the functionality of domestic financial markets; FX liquidity was improved through two-way O/N FX swap quick tenders and an overnight FX swap standing facility from the €5 billion credit line provided by the ECB. Forint liquidity was enhanced through a reduced reserve ratio, two-week, fixed-rate, and weekly collateralised loan tenders, six-month, variable-rate collateralised loan tenders, as well as secondary market government securities purchases (MNB 2008). The range of eligible collateral was also expanded and made more similar to the set of instruments applied by the ECB.

Polish commercial banks also suffered from limited access to financing currency positions due to the turmoil in international financial markets. Therefore, the Polish National Bank introduced the so-called Confidence Pact in October 2008 to (1) enable banks to obtain financing in the zloty with 7-day and 3-month maturity repo transactions, (2) enable banks to obtain foreign currency financing through FX swaps (USD/PLN, EUR/PLN and CHF/PLN after November) with 7-day and 3-month maturities, and (3) extend the list of securities that were acceptable in transactions with the NBP (NBP 2009). A $20.6 billion IMF Flexible Credit Line was provided for Poland in May 2009 for a one year period, but it was not used (IMF 2009, NBP 2010).

The Czech National Bank also applied reverse 2-week repos and foreign exchange swaps (3-month CZK/EUR) as extraordinary operations to increase liquidity in the secondary government bond market and other channels for banks. However, Czech domestic short-term interest rates were lower than the corresponding rates in the euro-area for most of 2008, as was the case in the previous three years, until euro interest rates fell sharply below Czech rates in the second half of the year. The Czech Republic adopted the role of a “safe haven” in the first half of 2008, but a rapid outflow of short-term investments followed (CNB 2009).

Inflationary pressure eased due to declines in commodity prices; therefore, most central banks with inflation targets (the Bank of England and The Swedish National Bank) decreased their policy interest rates in the fourth quarter of 2008 in response to the weakening economic outlook

and the intensification of the global financial crisis. However, the Czech, Hungarian and Polish national banks were only able to decrease their policy rates in November and December, after gaining liquidity through official channels in October.

The experiences of the liquidity disruptions in 2008 are reflected in both the concepts of the new capital and liquidity adequacy regulations in Basel III (Ács 2011) and the *Global liquidity – concept, measurement and policy implications report* of the BIS (2011). The latter clearly states that the role of official liquidity is inevitable when private (market and funding) liquidity declines to an extreme level: central banks are able to provide liquidity in domestic currency, however foreign currency can only be provided through foreign exchange reserves, swap lines between central banks, or dedicated facilities such as IMF programmes.

In summary, this section indicates that foreign exchange markets and foreign currency liquidity play fundamental roles in the selected countries and indirectly and directly affect the government bond market. A Maastricht-type convergence seems to have disappeared between capital markets during the extreme days of 2008, underscoring the relevance of the first research question. The swap lines and collaboration between central banks proved to be essential (including on the level of FED-ECB relations, not only between ECB and CNB-MNB-PNB), but it is necessary to study the differences between ordinary and extraordinary periods in capital markets – focusing on the remarkable forms of collective behaviour.

4. Methodology

To demonstrate the existence of collective behaviours between markets on extreme trading days, it is first necessary to reject the efficiency of the selected markets. To meet the efficiency requirements put forth by Fama (1970), markets have to behave as a random walk describes them – returns should be normally distributed (Jarque-Berra test), without autocorrelation (Ljung-Box test) or heteroscedasticity (ARCH LM test), and should be stationery (ADF test) (Wong and Li 2010, Tsay 2005, Lütkepohl 2004). The rejection of market efficiency allows us to estimate contagions through the use of dynamic conditional correlation after ruling out heteroscedasticity with GARCH-models, following Cappiello et al. (2006).

Time series are generally biased by autocorrelation and heteroscedasticity because of the fat tails of the return distributions and volatility clustering. The different versions of Bollerslev's (1986) Generalised Autoregression

and Heteroscedasticity (GARCH) models are widely used methods to provide homoscedastic, standardised residuals. The Asymmetric Power GARCH (APARCH)[6] model (4) developed by Ding et al. (1993) may be the most powerful tool to address the heteroscedasticity bias that results from the asymmetric, fat-tailed assumptions of the distribution:

$$\sigma_t^{\delta} = \omega + \sum_{i=1}^{p} a_i \left(\left| \varepsilon_{t-1} \right| - \gamma_i \varepsilon_{t-1} \right)^{\delta} + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^{\delta} , \qquad (4)$$

where ω is a constant term, α denotes the impact of news, $-1 < \gamma_i < 1$ is responsible for the asymmetry function, β is the level of volatility persistence, and $\delta > 0$ provides nonlinearity. The parameters of APARCH have to be defined: "p" and "q" determine the lag numbers of the residuals and volatility, while "o" is a non-negative scalar integer representing the number of asymmetric innovations. A further advantage of the APARCH model is its flexibility – it is simple to convert it to the GJR GARCH and TARCH models and the basic GARCH form. The lag length was optimised on a 1-to-4 scale and selected according to the estimation's Akaike Information Criteria (AIC).

As Forbes and Rigobon (2002) suggest, ordinary cross-correlation is not a suitable tool for specifying the common movement of markets because of heteroscedasticity. Cointegration is also ruled out because it is better to analyse long-term processes; hence, BEKK-GARCH or DCC-GARCH could be adequate solutions following the APARCH step.

This study applies DCC-GARCH[7], following Engle (2002), to analyse the daily common movements of the selected markets. Cross-market correlation is compared using the Ansari-Bradley test because this variance test is not based on the assumption of a normal distribution – as is the case for the widely used t-test. After the identification of common market movements, it is necessary to separate them on the basis of the hub return's extremity or normality.

How can we separate the "extreme" and "ordinary"? Jentsch et al. (2006) defined extreme events[8] by their impact and probability – hence,

[6] The estimation based on the UCSD toolbox, developed by Kevin Sheppard: http://www.kevinsheppard.com/wiki/UCSD_GARCH

[7] The estimation based on the Oxford MFE toolbox, developed by Kevin Sheppard: http://www.kevinsheppard.com/wiki/MFE_Toolbox

[8] Definition: *Extreme event* (4) is a $w_x \in W$ event for a W stochastic variable with a $w_x >> w_n$ or $w_x << w_n$ significantly higher impact than the expected in

we have to find a suitable threshold or milestone to form both groups. There are multiple solutions (see Campbell et al., 2002), but this study focus on the fatness of the tails; therefore, it is necessary to separate the empirical distribution by fitting a theoretical normal distribution to it. Therefore, it is reasonable to define extreme returns on the basis of the extreme event definition – that is, "shocks" were the product of the transition from the normal to the extreme return subset.

Definition: *Extreme return* (5) is the extreme change of the m_j market on the fat tails of the r^{m_j} return's probability distribution. This event is related to the skewness of the distribution, while their probability and value differ starkly from the $E(r)$ expected.

$$r_x >> E(r) \text{ or } E(r) >> r_x \text{ where } p_{r_x} << p_{E(r)} \tag{5}$$

Definition: *Normal returns* (6) fit well on the projected theoretical normal distribution – therefore, they are denoted in the study variable r_n.

Definition: *Capital market shock* (7) means the $r_{n/x}$ transition of the return from the r_n normal subset to the r_x extreme subset. The $r_{n/x} \neq 0$ existence of this transition defines both subsets (6), while the totally normal distributed return indicates an $r_{n/x} = 0$ efficient market (7):

$$r_{n/x}^{m_i} \neq 0 \rightarrow r^{m_i} = \begin{cases} r_n^{m_i} \\ r_x^{m_i} \end{cases} \tag{6}$$

$$r_{n/x}^{m_i} = 0 \rightarrow r^{m_i} = r_n^{m_i}. \tag{7}$$

The entire time series can be divided (8) into extreme and normal subsets according to the above definitions:

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a limited time and space with a $p(w_x) << p(w_n)$ significantly lower probability than the expected, providing a uniqueness (Jentsch et al. 2006).

$$r\begin{cases} r_x\begin{cases} r_x^+ : r_{empirical,l} > r_{theoretical_{normal},l} \\ r_x^- : r_{empirical,i} < r_{theoretical_{normal},i} \end{cases} \\ r_n : r_{theoretical_{normal},i} < r_{empirical,k} < r_{theoretical_{normal},l} \end{cases} \quad (8)$$

where $r_{empirical,i}$ is the i th element of the empirical distribution and the $r_{theoretical_{normal},i}$ denotes the projected normal distribution, $i < k < l$.

Relying on the definition of QQ plots by Deutsch (2002, 690–691), the above separation can be expressed in the following way (9):

$$X_i = \phi_1^{-1}(P_i) = \phi_1^{-1}\left(\frac{1}{T}\right) \text{ for all } i < T \text{ , therefore,}$$
$$r_n \approx \mu_2 + \sigma_2 X_i \text{ ,}$$
$$r_x^+ > \mu_2 + \sigma_2 X_i \text{ ,}$$
$$r_x^- < \mu_2 + \sigma_2 X_i \text{ ,} \quad (9)$$

where X_i denotes the theoretical empirical standard normal distribution, which is represented in the QQ plot by a line with $\mu_2 + \sigma_2 X_i$ slope.

Contagions, divergences and interdependences initiated by one market's extreme days have to be detected for 10 inter-market correlations (6 for currencies). First, it is necessary to decide between interdependence (nonsignificant changes in correlations) and significant correlation changes (such as divergence and contagion) – this could be expressed by the overall weight of significantly different correlations (10):

$$\frac{\sum\left(S_{m_1m_2}, S_{m_3m_4}, \ldots, S_{m_jm_k}, \ldots, S_{m_{n-1}m_{n-2}}\right)}{N} \begin{cases} >50\%, \text{ where is contagion or divergence} \\ \leq 50\%, \text{ where is interdependence} \end{cases} \quad (10)$$

where $s = \begin{cases} 1, \text{when correlations are significant different} \\ 0, \text{when correlations are nonsignificant different} \end{cases}$, N denotes the number of involved market pairs. Contagions are characterised by significantly higher correlations and divergences are characterised by significantly lower correlations according to the definitions (11). To select between these two forms, the following algorithm was used:

$$g=\begin{cases}1,if\left(\rho_{na}=\begin{cases}0,if\ s=0\\ \rho_n,if\ s=1\end{cases}<\rho_{xa}=\begin{cases}0,if\ s=0\\ \rho_x,if\ s=1\end{cases}\right)\\ 0,if\left(\rho_{na}=\begin{cases}0,if\ s=0\\ \rho_n,if\ s=1\end{cases}\geq\rho_{xa}=\begin{cases}0,if\ s=0\\ \rho_x,if\ s=1\end{cases}\right)\end{cases},$$

Than

$$\frac{\sum\left(g_{m_1m_2},g_{m_1m_3},\ldots,g_{m_jm_k},\ldots,g_{m_{n-1}m_n}\right)}{N}\begin{cases}>50\%,\ where\ is\ contagion\\ \leq 50\%,\ where\ is\ divergence\end{cases} \tag{11}$$

Thus the contagion was expressed by weighting against the entire set of correlations, which is a strict rule.

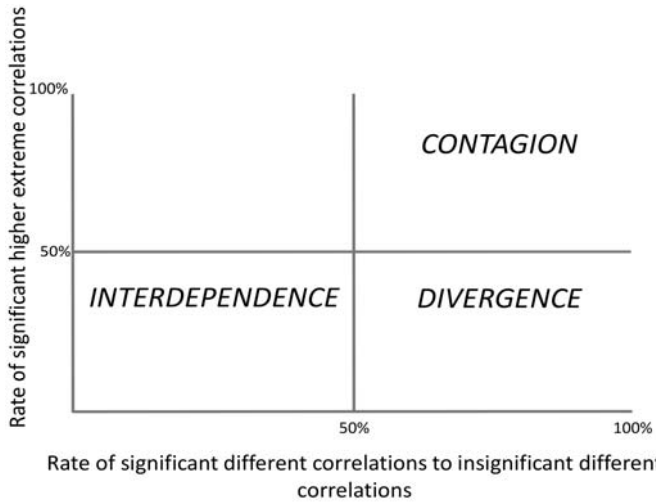

Fig. 9-1 Mapping the difference between contagion and interdependence
Source: Author's calculations

This approach (Figure 9-1) regards market developments in terms of whether they would be signs of shock or contagion. Therefore, a contagiousness ranking could be defined between the three CEE, US and euro zone markets, where markets could be scored according to the number of correlations divided into significantly different parts, and the extreme correlation should be higher on average. The results can be easily visualised in the following way: the "x" axis depicts the rate of significantly different and non-different correlations, while the "y" axis

depicts the number of observable correlations, where extreme values are higher than normal.

Although the need for monetary collaboration became obvious in light of the events of 2008, it was necessary to define the patterns that require monetary policy to be conducted with caution. The above methodology can be used not only to test for market efficiency (one of the presumptions of pre-crisis monetary policy), but we are also able to separate the days when this efficiency was most biased (e.g., trading days with extreme returns), as well as the dynamics of common market movements and collective behaviour patterns.

5. Results

Our results are structured in the following manner: after the rejection of the classic form of market efficiency, the patterns of extreme price developments and common movements will be analysed. The impacts of the FED and ECB's monetary policies on the sample countries will be analysed using two event windows on the basis of the increasing and decreasing phases of these two important central banks' main refinancing rates.

According to the results in Table 9-1, the lack of a normal distribution and the heteroscedasticity and autocorrelation of the time series ruled out the classical form of market efficiency. These properties suggest volatility clustering and more frequent extreme jumps in the first differentials of bond market yields, currency rates and stock market indices.

High kurtosis (exceeding the level of 3) could be interpreted as a clear sign of fat tailness and extreme changes, which occurs with enormous magnitude in the bond markets – in contrast to the stock and currency markets with their moderate kurtoses. This result is remarkable, considering that changes in the 3-month yield are primarily affected by monetary policy and changes in international liquidity, while the unregulated stock markets and free-floating currencies seemed to be smoother. The observed heteroscedasticity underlines the appropriateness of employing various GARCH models before estimating the correlations.

As the results in Table 9-2 suggest, heteroscedasticity was ruled out in all of the cases – consequently, bond markets required the highest lag number and the application of the developed GARCH model, while the stock and currency markets were less difficult. Volatility persistence seemed to be an important factor as the close-to-one level of the β coefficient suggests. Market participants and central banks were forced to operate in a market where volatility was self-enhancing.

Patterns of the common market movements differ between market types. Figures 9-2 to 9-5 illustrate the dynamic conditional correlation fluctuations.

Table 9-1 Statistics on market efficiency

Analysed markets	Skewness	Kurtosis	Normal distribution (Jarque-Bera)	Stationarity (ADF-test) 1 lag			Heteroscedasticity (ARCH-LM) 2 lag		Autocorrelation (Ljung-Box) 6 lag	
			p	t statistic		critical value	p		p	
US 3M	0.23	70.0669	0.001	-55.462	*	-1.9416	0		0	
EURO 3M	-0.02	42.0711	0.001	-51.2232	*	-1.9416	0		0.2245	***
HU 3M	1.3047	85.5834	0.001	-50.2077	*	-1.9416	0		0.8346	***
CZ 3M	-3.9396	63.4792	0.001	-46.9896	*	-1.9416	0.846	**	0.0033	
PL 3M	-0.7997	37.5076	0.001	-44.1657	*	-1.9416	0.0334		0	
US 10Y	-0.2763	8.4496	0.001	-52.3948	*	-1.9416	0		0.0188	
EURO 10Y	0.0321	4.96	0.001	-46.9331	*	-1.9416	0		0.0016	
HU 10Y	0.3541	14.6869	0.001	-47.6824	*	-1.9416	0		0.0171	
CZ 10Y	-1.6999	63.9912	0.001	-49.1197	*	-1.9416	0		0.3756	***
PL 10Y	0.6234	16.2843	0.001	-42.2279	*	-1.9416	0		0	
DJI	0.1068	12.2829	0.001	-55.5017	*	-1.9416	0		0	
DAX	0.107	8.2694	0.001	-52.2590	*	-1.9416	0		0.0276	
BUX	-0.093	9.9225	0.001	-47.6622	*	-1.9416	0		0.0178	
PX	-0.5618	17.8663	0.001	-46.4961	*	-1.9416	0		0.0003	
WIG	-0.2971	6.2382	0.001	-46.3625	*	-1.9416	0		0.0002	
EUR/USD	-0.1148	5.2043	0.001	-49.7133	*	-1.9416	0		0.8173	***
HUF/USD	-0.476	7.275	0.001	-50.6851	*	-1.9416	0		0.464	***
CZK/USD	-0.2709	5,5867	0.001	-48.0621	*	-1.9416	0		0.0573	***
PLN/USD	-0.1601	8.5734	0.001	-50.0457	*	-1.9416	0		0.9433	***

*: stationary time series; **: homoscedasticity; ***: lack of autocorrelation

Source: Author's calculations

Table 9-2 Fitting GARCH model

analyzed markets	AIC	GARCH model	parameters																	residuals
																				ARCH-LM
US 3M	2.4777	aparch221	0.0105	ω	0.1925	α(1)	0.0236	α(2)	-0.626	γ(1)	0.9995	γ(2)	0.7836	β(1)	2.0406	δ				0*
EUR 3M	1.6261	aparch112	0.0210	ω	0.1985	α(1)	-0.241	γ(1)	0.2612	β(1)	0.5401	β(2)	2.1090	δ						0*
HU 3M	1.3282	aparch222	0.2087	ω	0.2031	α(1)	0.2864	α(2)	0.3180	γ(1)	-0.325	γ(2)	0.0000	β(1)	0.5103	β(2)	0.7890	δ		0*
CZ 3M	1.2870	aparch111	0.0547	ω	0.0157	α(1)	-0.999	γ(1)	0.9371	β(1)	0.4887	δ								0*
PL 3M	0.7049	aparch112	0.1502	ω	0.3115	α(1)	-0.291	γ(1)	0.1940	β(1)	0.3894	β(2)	0.6995	δ						0*
US 10Y	1.8623	gjr111	0.0055	ω	0.0173	α(1)	0.0360	γ(1)	0.9639	β(1)										0*
EUR 10Y	1.5155	gjr111	0.0036	ω	0.0115	α(1)	0.0403	γ(1)	0.9666	β(1)										0*
HU 10Y	1.5723	aparch112	0.0836	ω	0.2116	α(1)	0.2014	γ(1)	0.2997	β(1)	0.4807	β(2)	1.4632	δ						0*
CZ 10Y	1.4797	aparch112	0.5358	ω	0.0056	α(1)	0.9994	γ(1)	0.0502	β(1)	0.4051	β(2)	3.9999	δ						0*
PL 10Y	0.9395	garch23	0.0001	ω	0.2796	α(1)	0.0000	α(2)	0.2645	β(1)	0.0807	β(2)	0.3750	β(3)						0*
DJI	1.3527	aparch111	0.0153	ω	0.0522	α(1)	-1.000	γ(1)	0.9314	β(1)	1.3619	δ								0*
DAX	1.6331	tarch111	0.0264	ω	0.0000	α(1)	0.1346	γ(1)	0.9293	β(1)										0*
BUX	1.7794	gjr111	0.0673	ω	0.0551	α(1)	0.0681	γ(1)	0.8845	β(1)										0*
PX	1.5973	gjr211	0.0663	ω	0.0050	α(1)	0.0700	α(1)	0.1242	γ(1)	0.8303	β(1)								0*
WIG	1.5750	gjr211	0.0243	ω	0.0000	α(1)	0.0453	α(1)	0.0447	γ(1)	0.9180	β(1)								0*
EUR/USD	0.94313129	garch11	0.0023	ω	0.0468	α(1)	0.9490	β(1)												0*
HUF/USD	1.32536592	gjr112	0.0449	ω	0.0548	α(1)	0.1098	γ(1)	0.1467	β(1)	0.6939	β(2)								0*
CZK/USD	1.12197521	garch11	0.0036	ω	0.0436	α(1)	0.9512	β(1)												0*
PLN/USD	1.2732017	aparch112	0.0240	ω	0.1140	α(1)	-0.308	γ(1)	0.3790	β(1)	0.4950	β(2)	1.4620	δ						0*
*: no heteroscedasticity																				

Source: Author's calculations

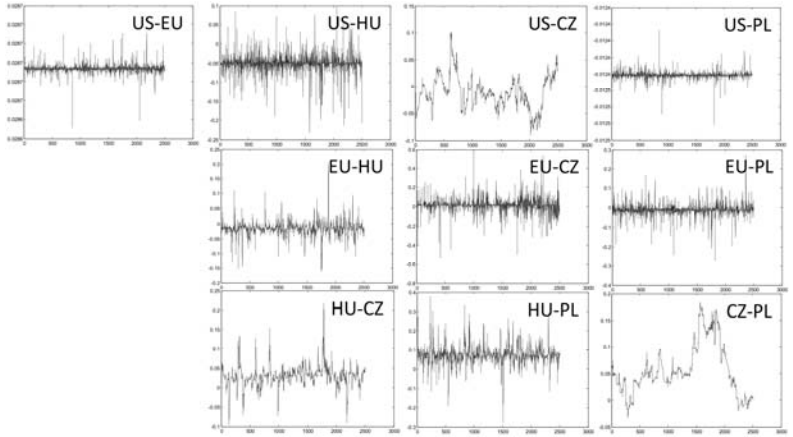

Fig. 9-2 Dynamic conditional correlation between 3-month yields
Source: Author's calculations

Three-month yields exhibit uncorrelated fluctuation, suggesting limited spill-over effects between these maturities in the sample countries. As this is the most liquid maturity and is targeted by monetary policy operations, it is difficult to find any evidence of interdependence or time-variance.

The appearance of the crisis after 2007 had more serious impacts on the 10-year yields, as Figure 9-3 presents. The pre-crisis weak correlation was neutralised by the crisis, which is our first piece of evidence to prove Bearce's (2002) divergence phenomenon. This result is considerable on the basis of the bond market convergence requirements in the Maastricht criteria – Central-East European countries' euro adoption was weakly priced in the pre-crisis era and totally ruled out during the crisis.

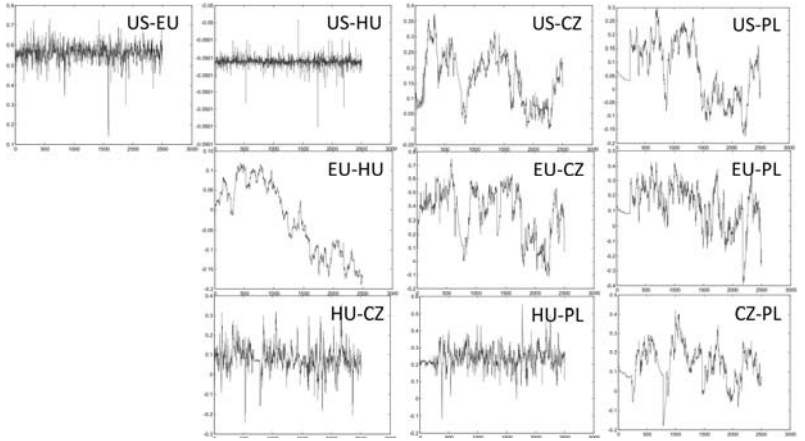

Fig. 9-3 Dynamic conditional correlation between 10-year yields
Source: Author's calculations

There was a correlation between stock markets, as Figure 9-4 suggests. Stronger economic ties between German and emerging European countries implied high correlation compared to the weaker correlation between the US and the other markets in the sample. The strength of the common movement increased dramatically in the second half of the decade – thus, it was already high before the crisis appeared; which is similar to the results obtained by Obstfeld and Taylor (2002) and Goetzman et al. (2005).

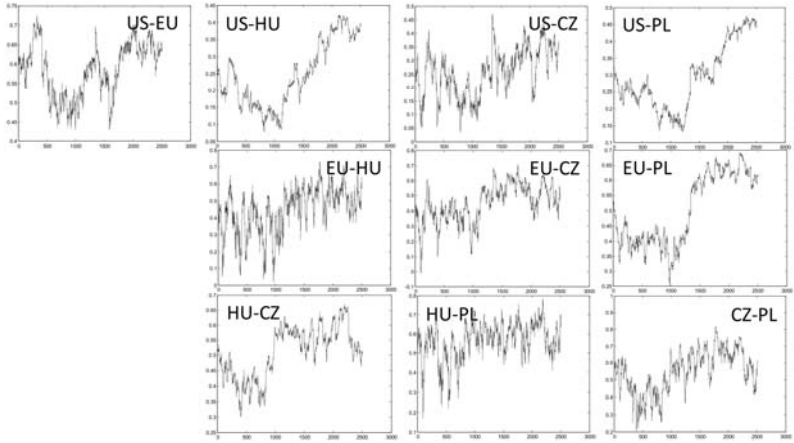

Fig. 9-4 Dynamic conditional correlation between stock markets
Source: Author's calculations

Contrary to the observed weak 10-year bond market convergence, the selected currencies exhibit strong correlation (see Figure 9-5), as shown by Stávárek (2009) and Babetskaia-Kukharchuk et al. (2008). This strong common movement is surrounded by several declines, suggesting there are atypical days when emerging currencies have to follow their own course.

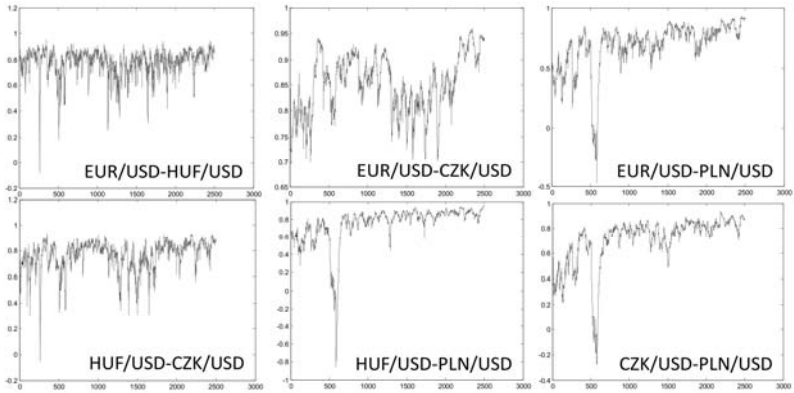

Fig. 9-5 Dynamic conditional correlation between currency pairs
Source: Author's calculations

Table 9-3 Properties of extreme trading days

analyzed markets		US 3M	EUR 3M	HU 3M	CZ 3M	PL 3M	US 10Y	EUR 10Y	HU 10Y	CZ 10Y	PL 10Y
extreme "+"	No	36	60	73	23	60	100	103	91	33	85
	%	*1,44%*	*2,40%*	*2,92%*	*0,92%*	*2,40%*	*4,00%*	*4,12%*	*3,64%*	*1,32%*	*3,40%*
	r	44,79	6,201	3,054	2,278	1,192	3,235	2,144	2,559	2,628	1,57
ordinary		2431	2395	2399	2457	2356	2335	2334	2357	2439	2344
extreme "-"	No	36	48	31	23	87	68	66	55	31	74
	%	*1,44%*	*1,92%*	*1,24%*	*0,92%*	*3,48%*	*2,72%*	*2,64%*	*2,20%*	*1,24%*	*2,96%*
	r	-43,27	-6,694	-3,164	-2,028	-1,143	-3,569	-2,433	-2,895	-2,647	-1,616
kurtosis	e	70,0669	42,0711	85,5834	63,4792	37,5076	8,4496	4,9600	14,6869	63,9912	16,2843
	n	15,2899	7,7186	6,4723	6,1227	4,7224	2,6959	2,6747	3,7812	4,3682	3,4725
analyzed markets		DJI	DAX	BUX	PX	WIG	EUR/USD	HUF/USD	CZK/USD	PLN/USD	
extreme "+"	No	70	47	36	18	67	29	34	29	39	
	%	*2,80%*	*1,88%*	*1,44%*	*0,72%*	*2,68%*	0,0115954	0,0135946	0,0115954	0,0155938	
	r	2,395	3,33	3,724	4,403	2,599	1,555	2,309	1,966	2,227	
ordinary		2355	2351	2409	2420	2332	2395	2353	2367	2359	
extreme "-"	No	78	105	58	65	104	77	114	105	103	
	%	*3,12%*	*4,19%*	*2,32%*	*2,60%*	*4,16%*	0,0307877	0,0455818	0,0419832	0,0411835	
	r	-2,334	-2,742	-3,284	-2,951	-2,212	-1,239	-1,738	-1,401	-1,748	
kurtosis	e	12,2829	8,2694	9,9225	17,8663	6,2382	5,2043	7,2750	5,5867	8,5734	
	n	3,2971	3,0827	3,0188	3,5862	2,8038	2,7427	2,8684	2,7738	2,8646	

Notes: No: numbers of days; %: ratio of extreme days to the entire sample; r: value of the first extreme return; e: endtire sample; n: normal days

Source: Author's calculations

According to these results, we are able make the following statements: 3-month yields and currency rates fluctuated around well-defined correlation levels, while the 10-year yields had a decreasing trend and stock markets had an increasing trend approaching the crisis era.

After the identification of the correlation curves and outliers, it is necessary to define "normal" and "extreme" in the sample markets days.

Trading days with extreme fluctuations were placed in the "extreme subset", as they do not fit the theoretical normal distribution in both of the tails of the empirical distribution (Table 9-3). These extreme days met the definition of extreme events: their mass is insignificant in the entire

sample, but they occur in the tails with low probability and high values. The validity of this method was verified by comparing the kurtosis of the entire sample to the subset of "normal" or ordinary days – the observed convergence to 3 was quite impressive.

Extreme jumps were distributed almost symmetrically in the case of the 3M market, while the first extreme return had the highest magnitude. Extreme yield increases characterised the 10Y market; this asymmetry is underlined not only by the number of days but also by the smaller first extreme return. Asymmetry characterised both the stock and currency markets on their negative side – the increased mass of extreme drops is clear in the case of the stock indices, but the currencies were characterised by extreme days primarily after the strength of the currencies had improved substantially.

After the introduction of time-varying correlation patterns and extreme change properties, it is necessary to make a brief comparison between "subsample A" (increases in the main refinance rates of the ECB and FED) and "subsample B" (decreasing interest rate period) for all of the markets.

Considering the shorter period of the ECB refinancing-rate changes – a 34 month increase and 36 month decrease compared to the FED's 42 and 47 months – there are two common phenomena (Table 9-4). First, the 3-month yields generally declined when the central banks reduced the main refinancing rates – implying some type of implicit spill-over effect between monetary policies. However the decline in 10-year yields was not a broad success, Central-East European national banks had to contend with increasing long term yields in contrast to the general decline in the euro zone and the US. The shapes of the yield curves became steeper in the entire sample, but they were the sharpest in the centre. A maturity transformation in a banking system requires this positive shape of the 10Y-3M spread under constant price level expectations. All of the currencies appreciated against the USD with increased volatility in the interval "B", while the stock indices were generally devalued according to ECB's monetary decisions – the FED windows produced a different outcome.

Table 9-4 Market differences under increasing and decreasing interest rates

central bank		ECB					FED				
markets		US	EUR	HU	CZ	PL	US	EUR	HU	CZ	PL
3M	mean "A"	3.809897181	3.5003	7.5218	3.0487	4.8834	3.834701958	2.6703	7.6137	2.3492	4.9094
	variance "A"	*2.061284042*	*0.361*	*0.7361*	*0.5813*	*0.8121*	*1.521848281*	*0.519*	*2.2822*	*0.1307*	*0.9910*
	mean "B"	0.125510778	0.7093	6.9252	1.8194	4.2992	0.761449082	1.6498	7.2524	2.4266	4.7550
	variance "B"	*0.012027703*	*0.2983*	*3.5459*	*0.7010*	*0.5364*	*1.325980386*	*2.3883*	*2.8827*	*1.4100*	*0.9820*
10Y	mean "A"	4.443556107	4.0302	7.2212	4.2229	5.5631	4.533348103	3.7753	7.0318	3.9982	5.5258
	variance "A"	*0.23584287*	*0.0954*	*0.3768*	*0.2221*	*0.1818*	*0.109197037*	*0.1401*	*0.4347*	*0.3113*	*0.4810*
	mean "B"	3.216767531	3.0693	8.0788	4.2510	6.0088	3.434390821	3.3910	7.9372	4.3725	5.9969
	variance "B"	*0.1834048*	*0.1264*	*1.6655*	*0.2821*	*0.0931*	*0.27888403*	*0.3550*	*1.3788*	*0.2493*	*0.0862*
10Y-3M spread	mean "A"	0.633658926	0.5298	-0.3007	1.1743	0.6798	0.698646144	1.1051	-0.5818	1.6490	0.6164
	variance "A"	*1.044591812*	*0.1770*	*0.4704*	*0.1673*	*0.3369*	*1.017479763*	*0.3019*	*1.1300*	*0.1617*	*0.4262*
	mean "B"	3.091256753	2.3600	1.1537	2.4316	1.7095	2.672941739	1.7412	0.6848	1.9459	1.2418
	variance "B"	*0.180085116*	*0.2867*	*0.9540*	*0.5249*	*0.5545*	*0.750074321*	*1.1571*	*1.2308*	*0.9578*	*0.9718*
currency	mean "A"		1.3660	0.0054	0.0506	0.3692		1.2641	0.0050	0.0430	0.3142
	variance "A"		*0.0138*	*0.0000*	*0.0001*	*0.0028*		*0.0030*	*0.0000*	*0.0000*	*0.0007*
	mean "B"		1.3664	0.0050	0.0537	0.3352		1.4013	0.0053	0.0550	0.3609
	variance "B"		*0.0052*	*0.0000*	*0.0000*	*0.0006*		*0.0081*	*0.0000*	*0.0000*	*0.0025*
stock	mean "A"	12164	6632	23516	1588	48793	11264	5473	20459	1366	38962
	mean "B"	10206	5866	19493	1085	38942	10862	6196	20624	1236	41919

Source: Author's calculations

Dividing our samples according to the interest rate decisions of the ECB and FED was useful to separate the pre-crisis and crisis eras and to evaluate possible spill-overs to the emerging European sample, but it is difficult to identify any difference between the two approaches.

The increasing and decreasing periods defined by the FED's main refinancing rate seemed a more appropriate tool to divide the sample markets' common movements into two significantly different components – at least 67% of the market pairs had significantly different correlations in this case (Table 9-5). This result is remarkable because 3M markets seemed to be uncorrelated before the crisis in addition to the consistently high common movements in the currency market. The results concerning the FED's leadership role could be biased by the different length of the two intervals.

Table 9-5 Significant differences in the common movement of the sample

central bank		ECB										
markets		US-EU	US-HU	US-CZ	US-PL	EU-HU	EU-CZ	EU-PL	HU-CZ	HU-PL	CZ-PL	%
3M	Significant difference between "A" and "B" periods	0	0	1	1	0	1	1	1	0	1	60%
10Y	Significant difference between "A" and "B" periods	0	0	0	1	1	1	1	0	0	0	40%
currency	Significant difference between "A" and "B" periods					0	0	0	1	0	0	17%
stock market	Significant difference between "A" and "B" periods	0	0	0	0	1	1	1	1	1	1	60%
central bank		FED										
markets		US-EU	US-HU	US-CZ	US-PL	EU-HU	EU-CZ	EU-PL	HU-CZ	HU-PL	CZ-PL	%
3M	Significant difference between "A" and "B" periods	1	1	1	1	1	1	0	0	0	1	70%
10Y	Significant difference between "A" and "B" periods	1	0	1	1	1	1	1	1	0	1	80%
currency	Significant difference between "A" and "B" periods					0	1	1	1	0	1	67%
stock market	Significant difference between "A" and "B" periods	0	1	1	1	1	1	1	1	1	0	80%

Source: Author's calculations

Therefore, it is necessary to study how the common movements differ under the extreme days defined by US and euro-area benchmarks for the entire sample or the upper subsets. Figure 9-6 demonstrates that it is difficult to define collective behaviours during extreme events. The correlation of sample currencies during the strong appreciation of the euro indicated divergence, meaning a weaker correlation as opposed to the general strong one. However, contagions were identified using the shorter ECB subsets, while the broader FED subsets indicated only interdependence. 3M markets generally exhibit interdependence, as do those of the 10Y, where only the entire sample-based EUR10Y indicated divergence, which means that weak correlations occur when the yield curve decreases substantially, e.g. during monetary expansion, ruling out the possibility of liquidity providing monetary spill-overs between central and emerging countries. During severe decline in the stock markets, only the entire-sample based on the Dow Jones Industrial Average was able to identify contagions – DAX and various subsets indicated only interdependence. The widely accepted hypothesis of trade-relation-based common movements was rejected because of this result and because the stock markets are not consistently interconnected.

Figure 9-7 presents divergences between currencies when the euro depreciated substantially against the USD according to the ECB subsets; sample currencies with weakened correlations are able to depreciate more extensively or remain stable. The 3M markets remained interdependent, but the US10Y market in the entire subset was able to indicate divergence when it increased substantially, meaning loosening common movements under monetary tightening and scarce liquidity. The entire sample based Dow Jones Industrial Average remained able to identify contagions only when the index increased substantially, and “A” periods present a nearly identical picture.

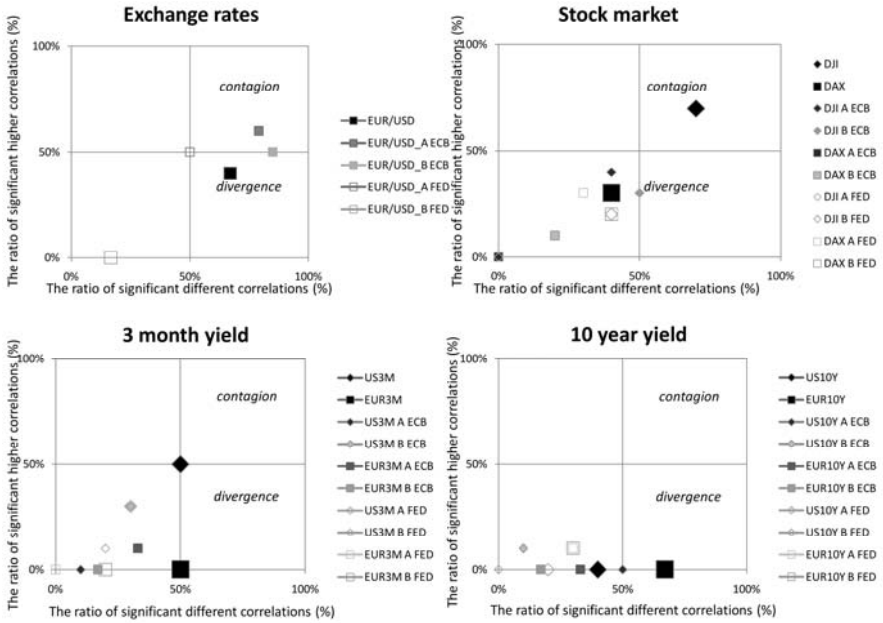

Fig. 9-6 Map of possible contagions, divergence and interdependence, comparing ordinary and negative extreme changes
Source: Author's calculations

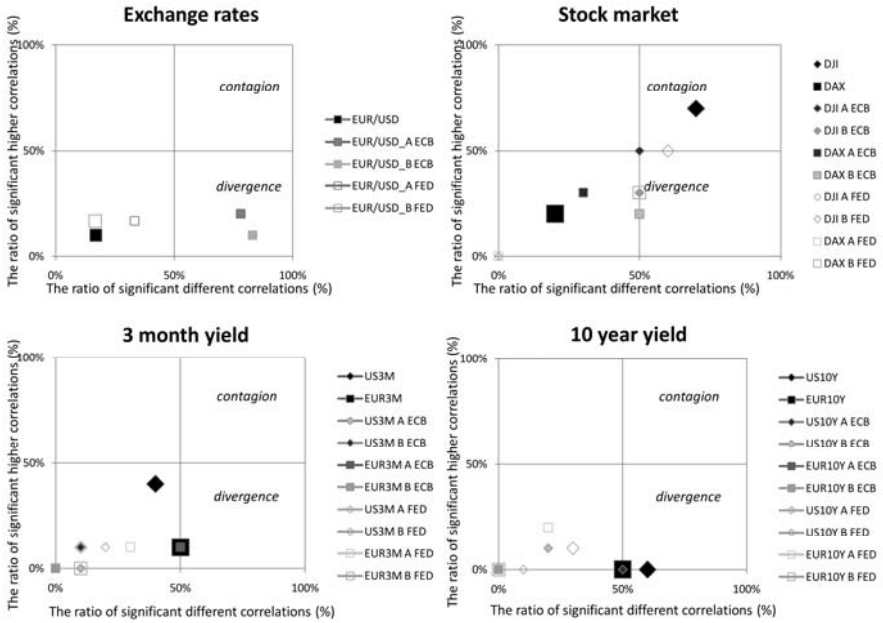

Fig. 9-7 Map of possible contagions, divergence and interdependence, comparing ordinary and positive extreme changes
Source: Author's calculations

These results suggest that thinking of collective behaviour is necessary: cross market-correlation is able to change on the days when one market undergoes extreme changes, but it is difficult to identify such differences in subsets, such as those representing the pre-crisis and crisis periods.

6. Conclusion

The operational autonomy of monetary policy is narrow in the selected Central-East European countries – and the range of decisions is even narrower under turbulent market conditions. The experiences during the crisis in the fall of 2008 underlined that even the former "safe haven" of the Czech Republic required FX liquidity trough swap lines, and the European Central Bank, the Federal Reserve and the Swiss National Bank faced the same problem on a larger scale.

This paper applied a diagnostic model to explore the phenomena that occur in and between markets on extreme trading days. After the rejection

of the efficient markets hypothesis, the dynamic, conditional correlations of the markets were analysed under extreme and ordinary trading days to identify the particular forms of collective market behaviours.

Maastricht-type convergence between the selected bond markets was already missing or had disappeared during 2008 due to the crisis, while free-floating currency markets tended to move together without any explicit monetary policy goal. Stock markets, as a control variable, tended to move together in a different way – correlation increased shortly before and during the crisis. The selected markets moved together in a significantly different way than before the FED began to reduce its prime rate, in conjunction with the ECB's decision to ease liquidity conditions without any change in the policy rate. Free-floating exchange rates exhibited that rates were strongly correlated with each other, but these trends were also significantly different under the tight and expansionary monetary policies of the ECB and FED. Contagions and divergence both characterised the currency markets; therefore, investors have to be cautious regarding exchange rate risk. Trade relations characterised stock market correlations well, but contagion between stock markets was only indicated by the Dow Jones Industrial index.

Yield curves' long maturities generally reflected long run risk premiums and inflation expectations. Individual national currencies make it difficult to adapt to downward changes in the principle currencies' yields – even real economies are tied strongly together through trade, corporate ownership and the banking sector, and the primary goal of monetary policy is the same and institutions are harmonised. The Czech, Hungarian and Polish bond and currency markets generally had to contend with loosening connections during difficult times: shocks affected them to a greater extent, while monetary activism was poorly implemented. The monetary autonomy of these countries will not decline after they adopt the euro in the future because this autonomy is also narrow in the present, and its maintenance requires expensive programmes and collaborations. Inflation-targeting monetary policy in the CEE was able to reduce inflation in all of the sample countries, but it was far from effective in reducing the probability of a banking crisis or bond market noise – due to its inability to influence the common lending channels between the euro zone headquarters and CEE subsidiaries of the regional banks. Therefore, we can conclude that inflation-targeting monetary policies have to be maintained in the region, but the free movement of capital and financial innovations requires that central banks increase their institutional capacities both in terms of financial stabilisation and their regional cooperation.

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